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Enhanced Electrohydrodynamic Pumping at the Microscale

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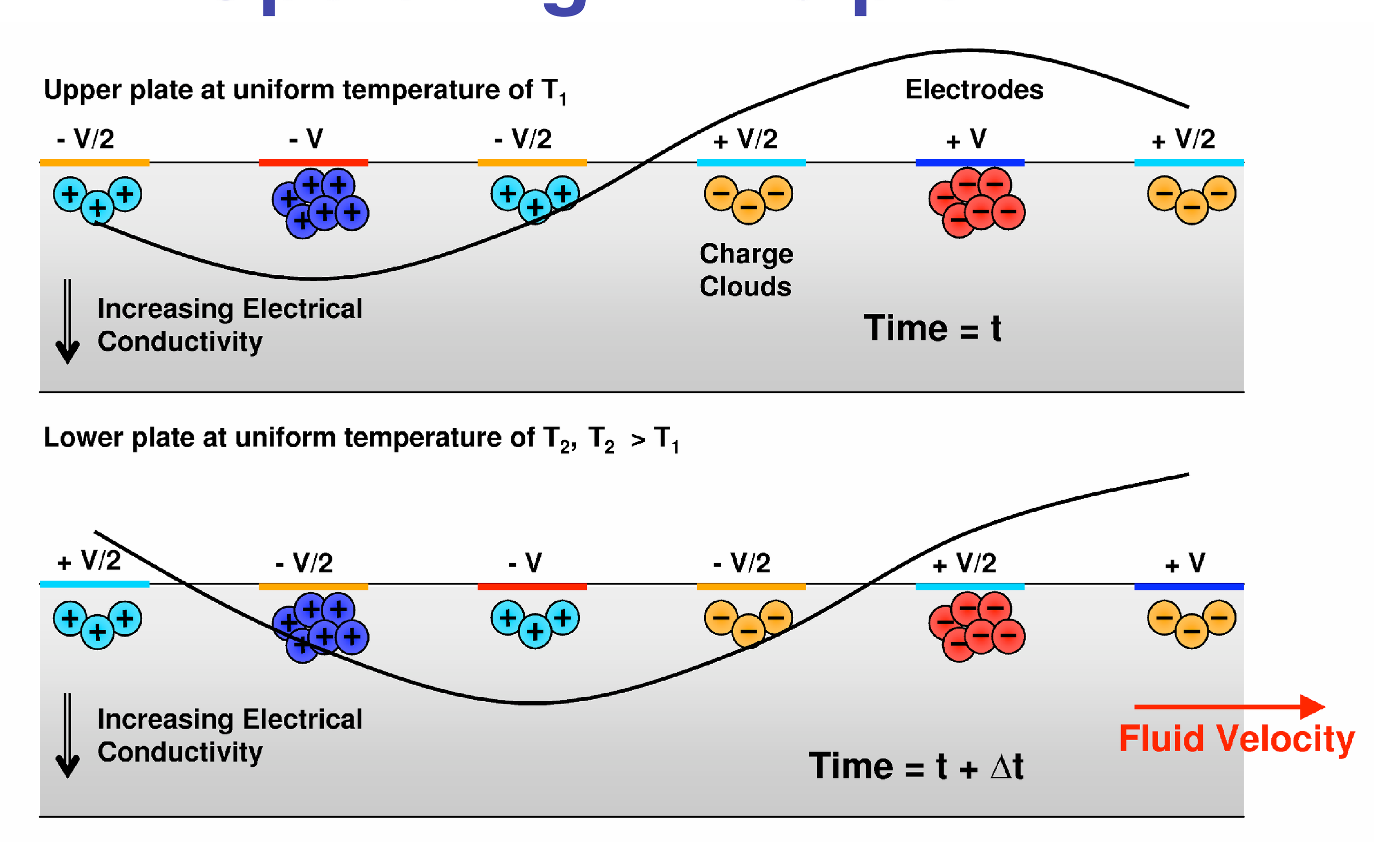
Abstract
An enhanced electrohydrodynamic micropump for use in small-scale liquid pumping applications is developed. The micropump can be incorporated into an integrated circuit chip to provide active cooling or used as a fluid delivery agent in microdevices. Liquid flow is achieved by combining two actuation mechanisms: electrohydrodynamics (EHD) and the action of a vibrating diaphragm. Heat generated by active devices creates a thermal gradient in the fluid allowing induction of ions to be driven by EHD. The vibrating diaphragm enhances the EHD efficiency, allowing more pumping power to be transferred to the fluid. Boundary condition effects, as a result of scaling, are considered through numerical modeling. Flow rate enhancement with the addition of a vibrating diaphragm is also presented.

Operating Principle

EHD



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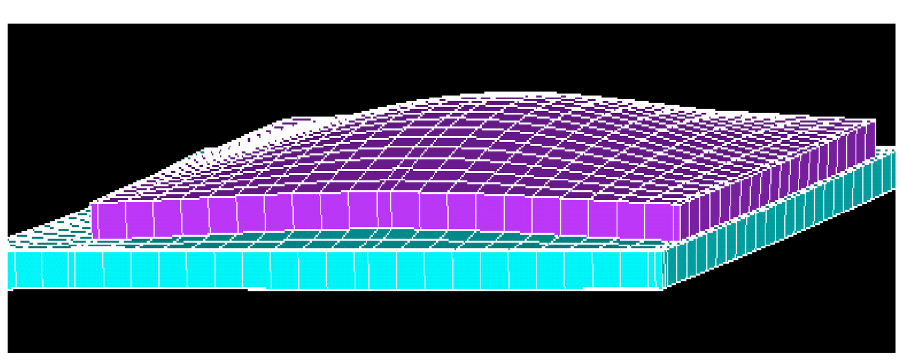
Diaphragm Vibration



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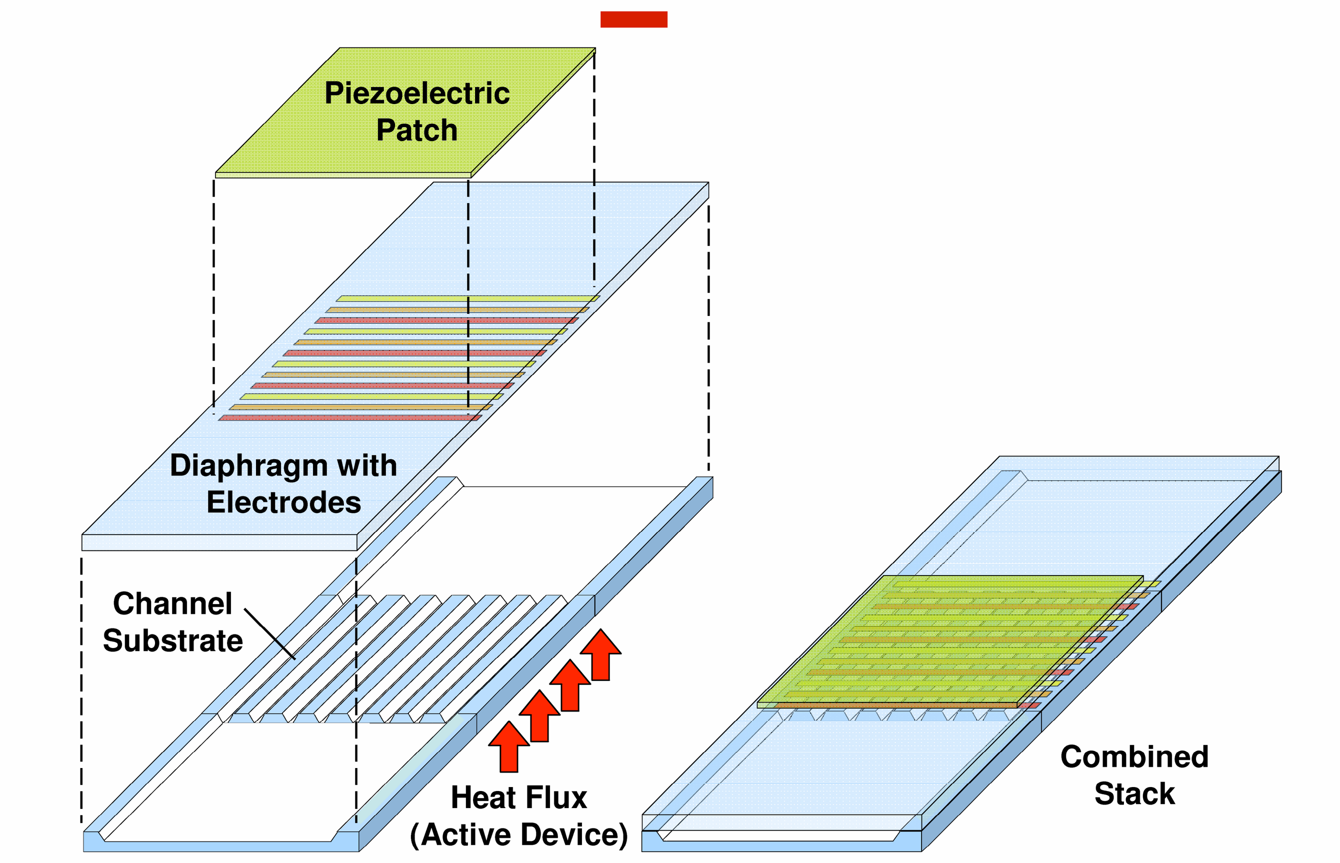
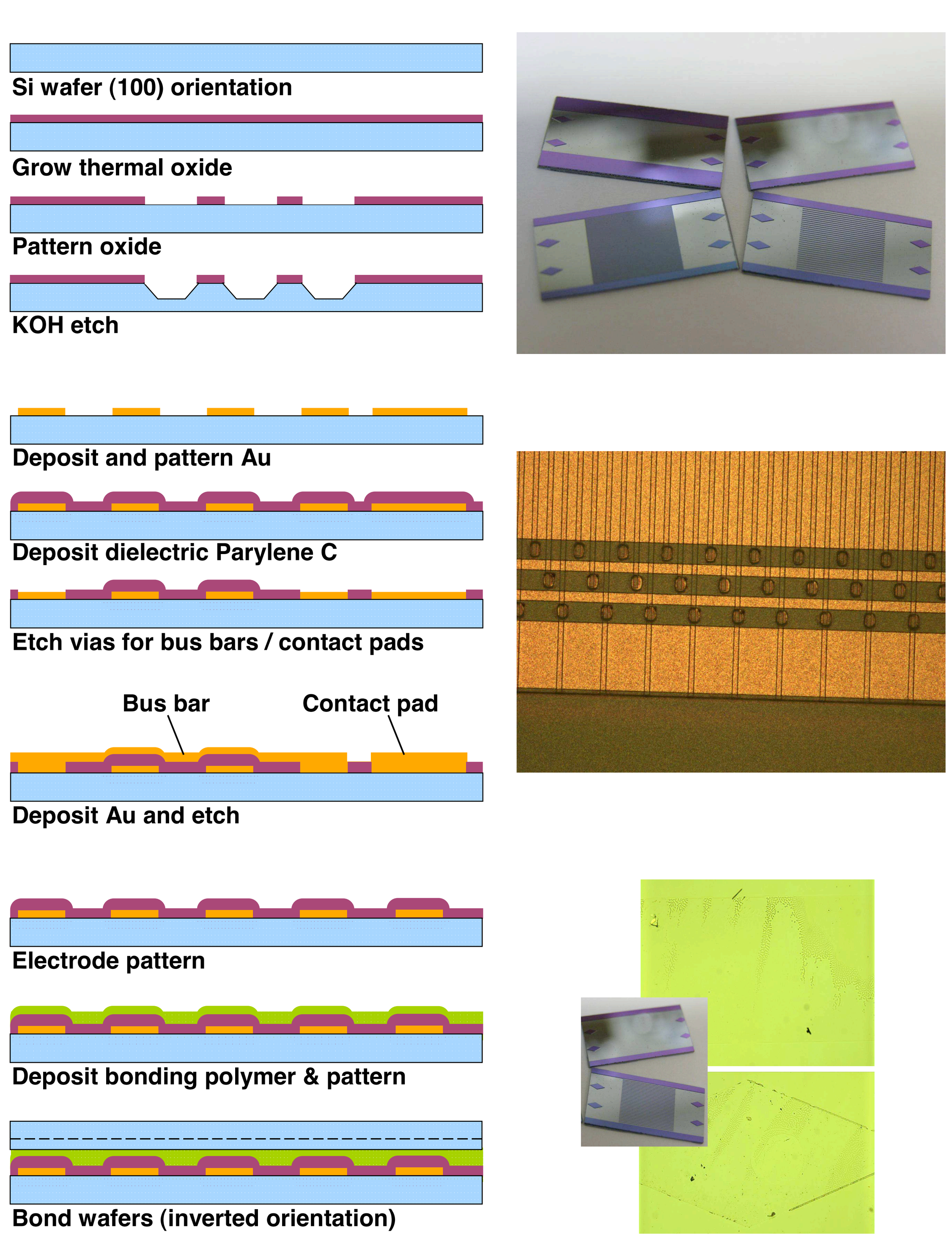
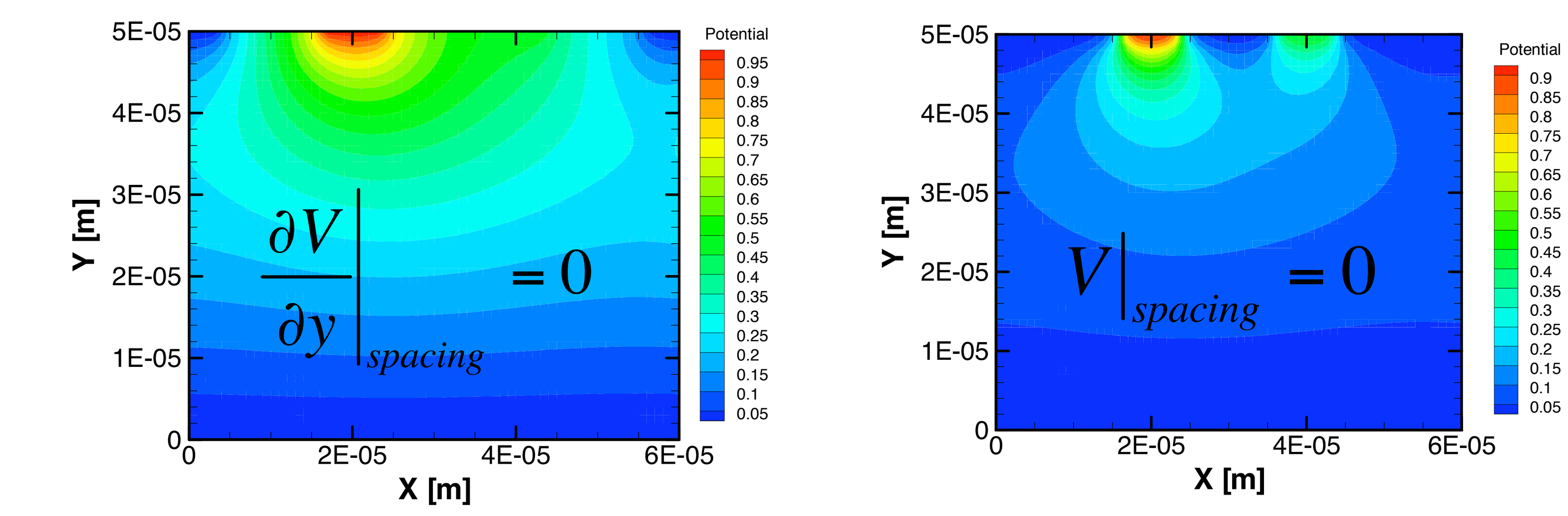
Device



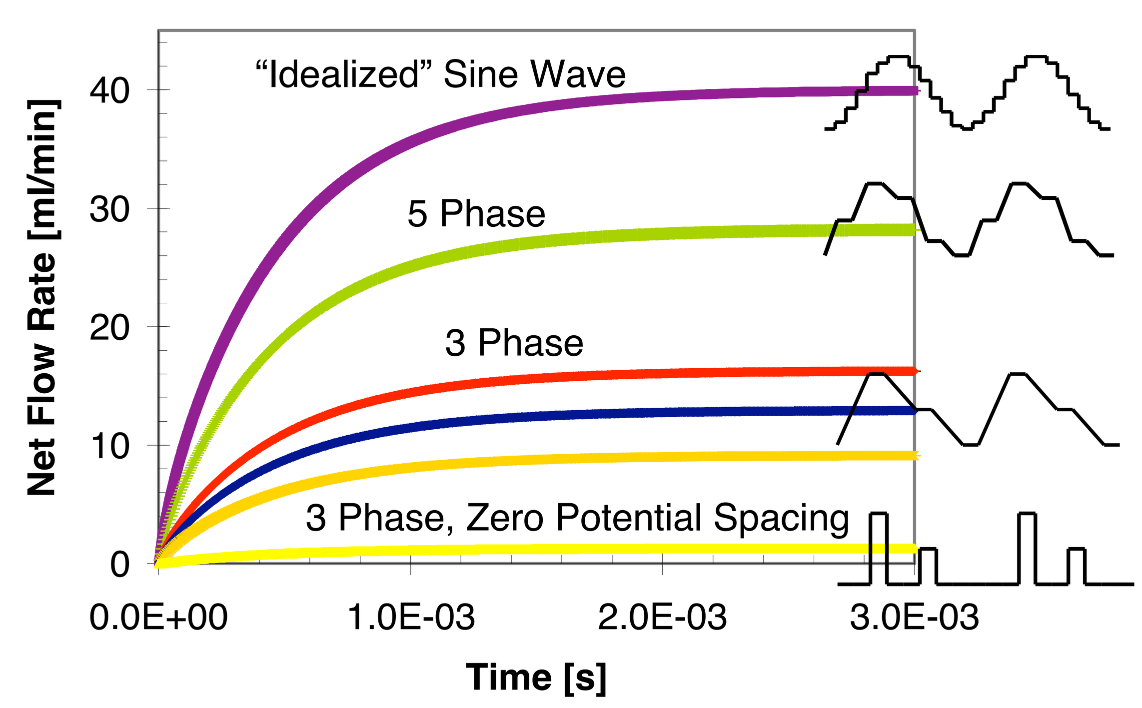
Fabrication



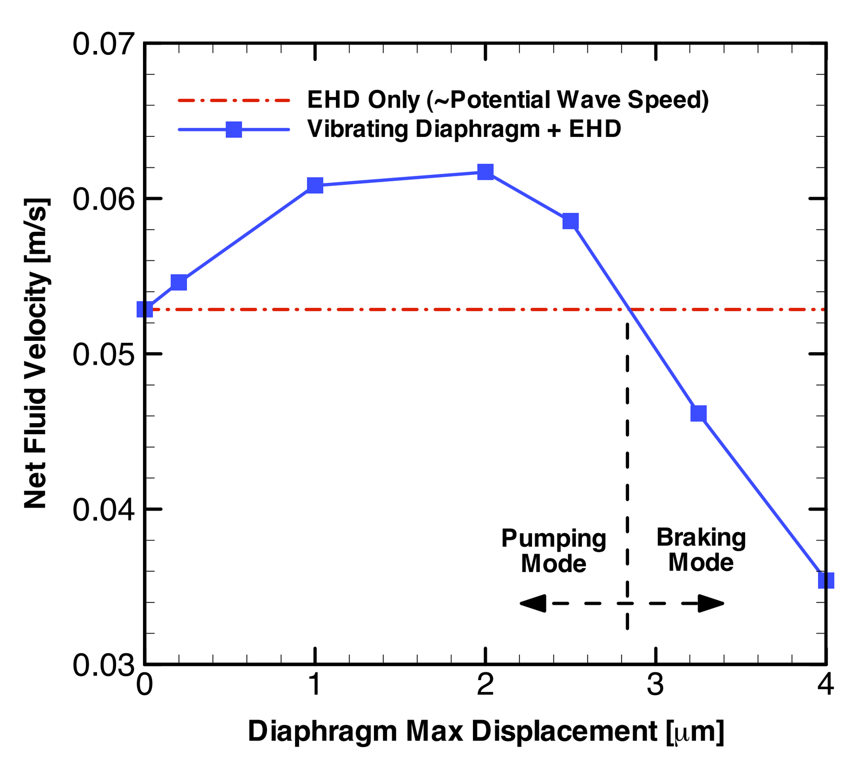
Key Results

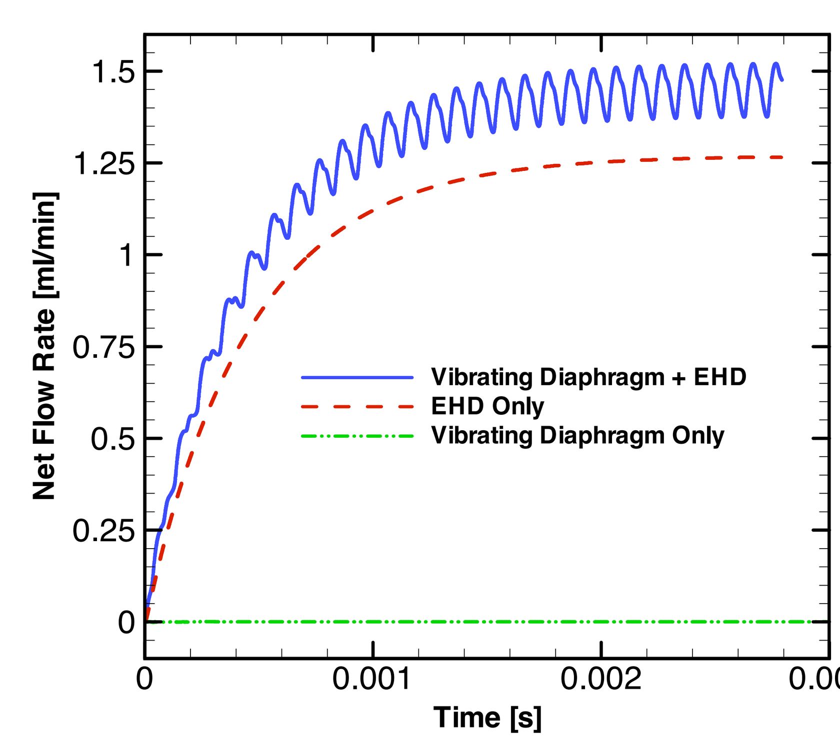


- Insulation boundary condition selection plays a significant role in the magnitude and gradient of the potential used to drive the flow.



- Distribution of assigned potential significantly affects flow rate from EHD.





- Optimum traveling wave frequency ($f = 1/2\pi\tau$) corresponds to the charge relaxation time ($\tau = \varepsilon/\sigma$) and is a function of the temperature-dependent fluid properties.

Impact and Conclusions

- Micropumping can increase power dissipation while maintaining a small form factor.
- Packaging thermal resistances are minimized by having the fluid in closer contact with the chip.
- Liquid cooling provides flexibility in component constraints and layout.
- An optimum diaphragm displacement exists such that the EHD pumping enhancement is maximized.
- Large diaphragm displacements move the fluid faster than the potential wave speed and cause fluid braking.
- An enhancement of approximately 18% was observed for a diaphragm displacement of 2 mm.

Selected References
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